

# The compositions of anhydrous and H<sub>2</sub>O-undersaturated melts in equilibrium with refractory peridotites at 15 and 20 kb: implications for high-Ca boninite petrogenesis

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## Introduction

Pressure-temperature relationships of the mantle involved in magma genesis is an important constraint for geodynamic and petrogenetic models for the origin of magmatic suites. The reconstruction of primary magma compositions for mantle-derived magmatic suites is an important quantitative approach to reveal P, T conditions of magma genesis.

Subduction-related boninite suites have been a subject of numerous studies due to their potential importance for understanding supra-subduction zone evolution. A widely accepted point of view is that the primary melts of boninite suites are

formed at 8–10 kb and 1200–1350°C (e.g. Crawford *et al.*, 1989), and contain 12–17 wt.% MgO and broadly variable H<sub>2</sub>O (~1–7 wt.%). In contradiction to this view are recent estimates of high-Ca boninite primary melt compositions from the Troodos ophiolite and the north Tonga forearc, made on the basis of melt inclusion studies in magnesian olivine phenocrysts (Sobolev *et al.*, 1993; Sobolev and Danyushevsky, 1994), which indicate that these magmas contained 20–24 wt.% MgO and ~2 wt.% H<sub>2</sub>O, leaving a harzburgite mantle residue. However, the compositions of significantly H<sub>2</sub>O-undersaturated and anhydrous melts in equilibrium with highly refractory mantle residues at

Table 1. Compositions of starting materials and experimentally determined equilibrium melts

No	2PKI-38 -40%FO <sub>93.5</sub> 1	A-46 2	Melt layer 3	Troodos prim. melt 4	Tongan prim. melt 5	T-3488 6	T-3485 7	T-3494 8
SiO <sub>2</sub>	46.62	56.65	50.65	50.0	50.9	50.61	52.15	50.22
TiO <sub>2</sub>	0.05	1.15	0.68	0.2	0.1	0.72	0.73	0.58
Al <sub>2</sub> O <sub>3</sub>	0.65	14.40	8.50	10.7	6.9	8.21	8.17	5.97
FeO	4.91	10.08	8.73	8.2	9.1	8.55	7.43	7.94
MnO	0.15	0.20	0.12	-	0.2	0.09	0.14	0.15
MgO	46.41	2.56	20.20	19.1	23.8	21.39	20.83	26.22
CaO	0.73	7.06	6.93	9.4	6.3	6.64	6.51	4.93
Na <sub>2</sub> O	0.10	2.81	1.66	0.50	0.6	1.55	1.45	1.22
K <sub>2</sub> O	0.03	0.27	0.16	0.1	0.1	0.27	0.31	0.22
Cr <sub>2</sub> O <sub>3</sub>	0.34	-	-	-	-	0.13	0.37	0.47
H <sub>2</sub> O	-	4.1	2.36	1.8	2.0	~2.0	~2.0	~2.0
Total	100	99.15	100	100	100	100.16	100.09	99.92
P(kb)	-	-	-	~15	~17	20	15	20
T(°C)	-	-	-	~1430	~1470	1450	1450	1500
Fo	-	-	-	94	94	92.8	93.6	93.8

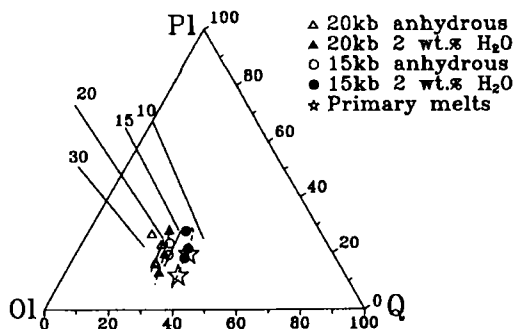


Fig. 1. Compositions of partial melts in equilibrium with harzburgite plotted in a molecular normative Pl-Ol-Q projection (Sobolev and Danyushevsky, 1994). Solid lines represent anhydrous isobaric (kb) olivine-orthopyroxene cotectics; dashed lines = cotectics with  $\sim 2$  wt.%  $H_2O$  in the melt.

high P and T have not been studied experimentally. To demonstrate that the proposed compositions are in equilibrium with a refractory harzburgite, and to establish the position of olivine-orthopyroxene cotectics for very refractory residues, we have performed sandwich-type experiments at 20 and 15 kb using high-pressure solid-media piston-cylinder apparatus at the University of Tasmania.

#### Experimental techniques

Experiments have been performed by a two-layered sandwich technique using graphite capsules sealed in outer Pt capsules. Analogues of a Troodos harzburgite 2PKI-38 and the calculated primary melt compositions for Troodos and Tonga high-Ca boninites have been used as starting materials. The harzburgite composition has been prepared as a mixture of pure oxides so that its composition corresponds to the recalculated composition of 2PKI-38 (Table 1, No 1). The recalculation procedure included 1) exchange of Fe to Mg so that  $Mg\# = 94$ , and 2) subtraction of 40% of olivine  $FO_{93.5}$  from the recalculated composition. The primary melt composition (Table 1, No 3) has been prepared by addition of calculated amounts of  $MgO$ ,  $FeO$ ,  $SiO_2$  and  $Al_2O_3$  to a hydrous natural glass A-46 from the Troodos ophiolite (Table 1, No 2). This

technique has been chosen to avoid possible  $H_2O$  loss during charge preparation. The total charge weight was  $\sim 11$  mg. For anhydrous experiments the primary melt powder has been dried at  $1000^\circ C$  for 24 hours. The  $H_2O$  content of the glasses quenched during experiments have been estimated by infrared spectroscopy. In anhydrous runs  $H_2O$  content was 0.15 wt.%, whereas in hydrous runs  $H_2O$  content was in the range 1.5–2.5 wt.%.

#### Results and conclusions

Our experiments demonstrate that the proposed primary melt compositions (Table 1, No 4 and 5) are in equilibrium with a harzburgite mineral assemblage at 15–17 kb and  $1430$ – $1470^\circ C$  (Fig. 1). Also the experimental results indicate that there is a significant change in the anhydrous olivine-orthopyroxene cotectic orientation in the refractory compositional range as projected into the basalt tetrahedron (Fig. 1). The low-T experiment at 20 kb has successfully reproduced the olivine-orthopyroxene cotectic position defined for more fertile compositions (e.g. Falloon *et al.*, 1988). The existence of a significant 'bend' in the projected cotectics has not been reported previously and demonstrate the need to consider fertility of mantle sources and residues in deducing conditions of melting from melt compositions. Olivine-orthopyroxene cotectics with 2 wt.%  $H_2O$  in the melt show a similar shape to the anhydrous cotectics. They are shifted slightly towards more quartz saturated compositions.

#### References

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